SUGGESTIONS TO ASTRONOMERS

FOR THE

OBSERVATION

OF THE

TOTAL ECLIPSE OF THE SUN

ON JULY 28, 1851.

DRAWN UP BY A

COMMITTEE OF THE BRITISH ASSOCIATION.

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General Committee of the British Association for the Advancement of Science.

Edinburgh, August 7, 1850.

Resolved,—

That a Committee, consisting of Sir John Herschel, the Astronomer Royal, Professor Forbes, and Professor Powell, with power to add to their number, be empowered to communicate with the astronomers of Pulkowa on the observations to be made at the next approaching Total Eclipse of the Sun, July 28, 1851; and to draw up Suggestions for the guidance of observers generally.

[The following Suggestions have been drawn up by the Committee above-named, with the assistance of M. Otto Struve of Pulkowa.]

SUGGESTIONS TO ASTRONOMERS

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OBSERVATION

OF THE

TOTAL ECLIPSE OF THE SUN,

ON JULY 28, 1851.

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1. The principal observations for which a total eclipse of the sun presents peculiarly favourable opportunities may be classed under the following heads :—

Observations applying specially to the physical structure of the sun and moon, as those of the corona, and of the rose-coloured prominences (seen so markedly in the eclipse of 1842).

Photometric, thermometric, and actino-chemical observations, illustrating the difference in the nature and amount of radiation from different parts of the sun's disc.

Optical observations, particularly on the state of polarization of the light in different phases of the eclipse, and on the phænomena of irradiation, and of distortion of a dark limb by the formation of beads or threads.

The phænomena of the first class have never been seen except in a total eclipse of the sun ; and they appear so deserving of attention (especially the red prominences, which, if belonging to the sun, indicate physical peculiarities of structure on a most stupendous scale, and perhaps of corresponding importance), that it seems highly desirable that the arrangements for observation should be planned with especial reference to them. For the observation of the phænomena of the other classes, the opportunities (though absolutely rare) are

much more frequent; they will, however, be most effectually secured by the same arrangements which secure those of the first class.

2. It is *à priori* probable, that the phænomena (especially those depending on prominences from the body of the sun) will not be the same when viewed from stations on different sides of the central line of the shadow's path; and such differences appear, in fact, to have been observed in the eclipse of 1842. This consideration at once suggests the propriety of placing some observers at no great distance from the southern boundary of the total obscuration, and others at no great distance from the northern boundary. Near the centre of the shadow's path, the picturesque effect of the eclipse is the greatest, the phænomena are most symmetrical, and the longer duration permits observers to watch the phænomena with greater coolness; and here also it seems desirable that competent persons should be planted.

It appears not improbable that some of the phænomena may change with a change of absolute time; and for this reason, as well as for eliminating the chances of weather, and for obtaining variations of appearance due to differences of climate and of hours of the day, it is desirable that observations be made at different points along the line of the shadow's path.

3. In examining upon a map the course of the shadow in this eclipse, it will be seen that Stavanger, Christiansand, Copenhagen, Lund, Ystad, Cöslin, Thorn, Lowicz, Zamosc, Tarnopol, Kaminiez, Odessa, Eupatoria, Gumri, Erivan, are south of the southern boundary, but probably not so far as to prevent their being used as convenient head-quarters from which an excursion for observation may be made: that Bergen, Grimstadt, Arendal, Helsingborg, Cimbrishamn, Bornholm, Kulm, Plock, Warsaw, Lublin, Vladimir, Brody, Nikolaiew, Kherson, Perekop, Feodosia, Redut-Kale, Achalzich, Schuscha, are within the southern boundary: that Friederichsvärn, Göteborg, Carlskrona, Kalmar, Danzig, Ostrolenka, Lomja, Bialystock, Brest-Litowsk, Jitomir, Machnowka, Lipowez, Uman, Babrinez, Jenikale, Tiflis, Schemacha, are nearly on the central line: that Christiania, Friederichstadt, Königsberg, Gumbinnen, Augustowo, Grodno, Slonin, Pinsk, Radomist, Kiev, Jelisawetgrad, Berdiansk, Stavropol, Gheorgiewsk, Wladikawkas, are within the northern boundary: and that Carlstad, Memel, Tilsit, Krementschug, Ekaterinoslav, Mariupol, Mosdok, Derbent, are at a small distance beyond the northern boundary.

4. Now it appears extremely desirable that, if possible, observers should arrange themselves in confederations, each confederation consisting of three directing-astronomers, who should by concert station themselves at three places respectively near the northern boundary, near the centre, and near the southern boundary; these places being not very widely separated in the longitudinal direction of the

shadow's movement. Thus Arendal, Friederichsvärn, Christiania; Kulm, Danzig, Königsberg; Warsaw, Ostrolenka or Lomja, Augustowo; Brody, Brest-Litowsk, Grodno; Nikolaiew, Babrinez, Jelisawetgrad; &c., would be favourable combinations. Two or three such confederations should be formed at different parts of the shadow's path.

5. It is desirable that, at each station, there should be three or four observers. One should be furnished with a telescope magnifying about twenty times, with a pretty large aperture; and this will probably be found the most important. A second should have a telescope magnifying 100 times. Each of these telescopes should have in its field, but not crossing the centre, two wires of an interval of 1′, or some other convenient distance, for giving an approximate measure of any small object which may be observed. It is desirable that by the position of these wires, or in some other way, the observer should be able rapidly to refer the positions of objects seen in the telescope to vertical and horizontal directions. A third person should have a watch or chronometer (if the error of the chronometer is known, the astronomical value of the observations will be increased, but their physical value will be equally great without it) and writing materials, and should be prepared at any signal first to note the time, and secondly, to write down the phænomenon. A fourth should observe the general appearances, as seen with the naked eye. If the party were more numerous, a good sextant, or other double-image instrument, might be found useful in the hands of one person.

6. It is important that the dark glasses used for observing the sun up to the moment of total obscuration be so mounted that they can be slipped off in an instant. And it is desirable that each telescope should be furnished with several dark glasses, some showing the sun with a red disc, some with a white or greenish disc. These may be mounted, in a form which admits of rapid change, in a sliding or a turning frame; or their cells may be fitted loosely with bayonet-notch. If the observer is satisfied with the use of one colour or combination for the dark glasses, no arrangement is more convenient than that of wedges of the coloured glass, achromatized (as to dispersion) by wedges of colourless glass; the intensity is then changed gradually by merely sliding the combination of glasses. It may also be desirable to possess the power of altering the aperture of the telescope rapidly: this perhaps may be done by attaching by hinges to the object-glass cell one or more flat rings, which can be turned off or on the object-glass by pulling a string at the eye end.

7. It is desirable also that the observers should be provided with some instrument for the measure of radiant heat, as a thermomultiplier (of a coarse kind) with galvanometer, an actinometer, or a simple thermometer with rough black bulb (whose indications will be more accurate if the bulb be inclosed in a glass sphere from

which the air is exhausted). In the selection of the instrument, it must be borne in mind that in Western Europe the sun will be high, and that the season of the year is (generally speaking) favourable to energetic radiation; and also that it is desirable that the observation with the selected instrument occupy as short time as possible. For meteorological observations, a dry thermometer and a thermometer with wet bulb (or other hygrometer) will probably suffice.

8. It would be most desirable also to be furnished with some apparatus for measure of the intensity of light, but we are unable at present to particularize any which can be considered unobjectionable. The appearance of a lighted candle will give some very rude information. The flame of a candle may also be used for giving a good idea of the intensity of light, by viewing the object, whose brightness is to be ascertained, through the flame (thus, in ordinary sunlight, the light of the sky near the sun is seen through the flame without apparent diminution; but the light of a full moon cannot be seen through it at all). For the observation of shadows, a graduated scale, several feet long, with a disc of white paper to be slid upon it, with its plane perpendicular to the scale, may be useful.

9. Some instrument should also be provided for ascertaining the state of polarization of the light. In the limited duration of a total eclipse, time is wanting for the use of instruments giving an accurate measure of the degree of polarization; for the rough estimation of the position of the plane of polarization, and of its general magnitude, perhaps a Nicol's prism, furnished with plates of quartz cut in Savart's manner, or a Savart's polariscope, may be found convenient and sufficiently accurate. For the observation of the sun's disc before the total darkness, a dark glass of some kind should be used with the Nicol's prism. A common glass prism should be provided for examination of the chromatic composition of the light.

10. At any fixed observatory within the path of the shadow, which is furnished with a telescope mounted equatorially, and moved by very good clock-work (adapted in its rate to the diurnal movement of the sun), it is extremely desirable that arrangements should be made for Daguerreotyping or Talbotyping the image of the sun, or of the light surrounding the moon when the sun is hidden. It is necessary to observe that materials of very different degrees of sensibility will be required in different stages of the eclipse; the light of the uneclipsed sun being intensely bright, and that of the corona surrounding the moon, or even that of the red flames projecting into the corona, being exceedingly feeble.

If the plate or paper be so sensitive to photogenic action that an image can be formed in a fraction of a second of time, no equatoreal movement will be required. If an image can be formed in one or two seconds, a rude equatoreal motion, such as may be given to a temporary stand, will probably suffice. If this motion is given

by hand, it must be done by turning a winch in accordance with the beats of a chronometer or the vibrations of a pendulum.

11. The observers at each station should be prepared with accurate computations of the local times of beginning and ending of the general eclipse, and of beginning and ending of total darkness, with particular attention to the accuracy of computation of the duration of total darkness. It will be remarked that the computation of duration admits of great exactness for places near the central line of shadow, but that it is liable to considerable errors for places near the north or south boundary. They should also have accurate computations of the position, with respect to the vertical, of the points of the sun's limb at which the general eclipse begins and ends, and of the points of the moon's limb at which the sun disappears and reappears: the latter will be liable to sensible error.

Every observer should be furnished with one or more cards, upon each of which a circle is described: upon one of these the points of beginning and ending of the general eclipse and of the totality are to be marked; the others are to be used for hasty records of the places of any remarkable phænomena during the eclipse.

12. The observations to be made, and the mode of proceeding, should be arranged some days before the eclipse, and should be fully described in written instructions, with which each observer should be so perfectly acquainted as to have little need to refer to them at the time. Two cautions, however, must be borne in mind. The phænomena about the time of total obscuration are so striking that the most perfect discipline will then probably fail, and it will be almost useless to prescribe any observations which will prevent the observers from looking about them for a few moments to see the wonderful spectacle. And the whole time is so short, that it will be very desirable that each observer's attention be confined to very few phænomena. No party, probably, will be able to make all the observations mentioned below; it will be desirable, therefore, carefully to select those which can be made with the greatest probability of success, and to give the utmost attention to those only.

13. A quarter of an hour before the first contact of the sun and moon, the observations of radiation with the actinometer, &c. should be begun. (These should be continued through all stages of the eclipse.) The commencement of an eclipse is a very indistinct phænomenon, and perhaps for the principal part of the time before the total obscuration little can be done except to make, from time to time, observations of radiation and meteorological observations. But when the limb of the moon crosses that of the sun at right angles, and afterwards, the observers will be well able to estimate (as far as can be done by the eye) the difference in the intensity of light on different parts of the sun's disc. From this time also it will be proper to examine whether the entire circumference of the

moon, or any portion of it external to its intersection with the sun's limb, can be seen. It may be necessary for this purpose to use a telescope with a small number of lenses, all the surfaces of which are well polished and perfectly clean.

14. When the lune becomes narrow, occupying about a quadrant of the sun's circumference, the state of polarization of the sun's light in different parts of that quadrant may be examined. In these and subsequent observations of the same kind, it must be borne in mind that the diffused light reflected from *air* will probably give traces of polarization, and it may be well in all cases to remark whether the brightest parts of the light under inspection are as evidently polarized as the faintest. Attempts should now be commenced for discerning whether a comparison can be instituted between the darkness of the shadows of a small object (as a pencil, or a small rod) formed by the sun and by the lighted candle; and whether the distance of the paper disc, when their shadows are equally black, can be ascertained. (If this is found practicable, this observation should be continued to and through the total obscuration.) The light should be analysed, in regard to its chromatic composition, by the use of a prism, and special record made as to whether any of the colours are unusually vivid or deficient. The general state of the sky and atmosphere should be carefully observed and fully recorded.

15. As the totality approaches, the sextant observer may measure the interval between the cusps; and the telescope observers should examine carefully the state of the moon's limb as to roughness, particularly in the central part (which will be the last to touch the sun's limb), and should carefully remark whether the moon's limb can be seen beyond the sun's limb. These observations should be made with rapid changes of the dark glasses. At the very time of completion of the obscuration, Baily's beads should be looked for, and if possible with change of the dark glasses, and with change of the aperture of the object-glass, and perhaps by putting the telescope, for a moment, out of focus. (See Appendix No. I.) It will probably be best, for the relief of the eye, that the observers should now and then quit the telescope for an instant. The time of total obscuration is to be communicated to the chronometer-bearer by a single syllable. It is to be remarked that, even though the error of the chronometer be not known, the accurate observation of the duration of the totality will give valuable information as to the diameters of the sun and moon, and as to the moon's latitude.

16. The naked-eye observer, in the mean time, is to look at the sun with a dark glass, occasionally changing the glass, occasionally trying the polarization, occasionally relieving his eye. He may also specially remark whether the colour of objects appears to change, and whether the light in different parts of the sky is differently coloured. But when the totality is near, he is

simply to observe, with the weakest of the dark glasses or (if possible) with the eye uncovered, and to note the way in which the light is distributed, as to intensity, in different directions round the sun; whether there are beams of light, and in what direction; whether there are the rudiments of a ring round the moon; whether there is any light on the side opposite the bright lune. It is recommended that he do not quit this observation for any other; but if a trustworthy person of good general observation were near, it would be desirable that he should remark whether there appears to be any fluctuation or trembling of the light which falls upon the ground and upon walls, and whether the shadow appears, as to sense, to sweep over the earth.

17. The important use of the photographic apparatus will commence shortly before the total obscuration. It will be desirable to take photographic images of the cusps, but it will be particularly desirable that they should be varied by causing the pencil of light to pass through a prism, so as to produce prismatic dispersion in the direction transverse to the cusp, and thus to exhibit on the plate or paper an actino-chemical analysis of the light which has passed at the highest degree of obliquity through the sun's atmosphere. When the sun is totally hidden, simple images should be taken, at several repetitions, if possible, during the obscuration.

18. On the instant of total obscuration the corona will be formed. It is important that the observer with the low-power telescope and the observer with the naked eye should be prepared to remark whether any part of the corona is visible before the sun is completely obscured, and in what order the complete ring is formed, whether all at once or by progress from one or more points. Also, whether the ring is equally broad in different parts, and what is the proportion of its breadth to the moon's breadth; whether it is double, or divided as a succession of annuli; whether it is divided by radial lines; whether its texture appears fibrous, and what is the position of the fibres; whether it is sensibly coloured; and, if possible, whether its light is polarized. The light should be examined by the dispersive prism, and the excess or deficiency of any particular colour recorded.

19. As soon as possible, and also as late as is prudent during the obscuration, an attempt should be made to judge whether the corona is concentric with the moon, or with the sun.

20. The moment that the sun's bright edge is eclipsed, the observer with the most powerful telescope should watch for the appearance of red prominences in the direction of the moon's advance. From this time to the end of the totality each of the observers should repeatedly examine the whole circumference of the moon, to discover whether there are any of these prominences visible. The observer with the most powerful telescope should devote himself entirely to this subject. If any are seen, it is of the utmost im-

portance to note whether they undergo any change; whether new ones appear, and in what part of the circumference; whether they increase on one side and diminish on the other, &c. For details on this very important observation, see Appendix No. II. The times of any striking phænomena should be recorded, no description beyond reference by a single word being attempted at the time; and their places should be noted on the card-circle.

21. The telescope-observers should endeavour to judge whether the disc of the moon is sensibly illuminated. Little confidence can be placed in the appearance of light, unless some of the larger spots can be seen. The sextant-observer should measure the moon's diameter. If there is leisure, one actinometer-observation should be made.

22. An attempt should be made (as has already been mentioned under article 14) to ascertain whether the light of the corona is sufficient to cast a distinguishable shadow, and whether a distance can be found for the candle at which the intensities of the shadows are sensibly equal. But it is certain that the light of the corona is extremely feeble, and the observer must therefore be prepared to remove the candle to a considerable distance. Some estimate may be formed of the intensity of light by remarking the distance at which the letters and figures of a book can with difficulty be distinguished. All observers, as far as possible, should use the same page: for instance, the title-page of the Nautical Almanac for 1851, or the title-page of these "Suggestions," in which the same type is used. To give this observation its greatest value, each observer should as soon as possible examine at what distance he can distinguish the same letters in full sunshine, and at what stage of twilight and in what position he finds the difficulty nearly the same as during the eclipse.

23. Should any stars or planets be seen, their places should be noted (mentally) sufficiently to enable the observer to identify them afterwards upon a celestial globe. In particular, the observer should note the place of the smallest star which he can see. The apparent colours of the stars should be noted; and the observers should also record what they judge to be the colours of the same stars when seen in a dark night.

24. Among the coarser kinds of observation to be made with the naked eye during the totality may be mentioned the following. Whether bushes of light radiate from the corona, in what number, and in what directions. Whether there are beams in the direction of the ecliptic, like pyramids with their bases united at the sun, in the manner of the zodiacal light. Whether there is a red band of light near the horizon, or in any part of it. Whether the outlines of hills can be seen. Whether the smoke of chimneys can be seen. Whether any plants (as the sensitive plant, the convolvulus, or the silk-tree acacia) close their leaves or petals. Whether animals appear frightened.

25. As the duration of the totality will be, in most places, approximately known, the chronometer-bearer should be prepared to give about *ten seconds'* notice to the observers of the re-appearance of light. At places near the north or south boundary this may be scarcely sufficient. Each observer should then remark,—first, whether there is anything peculiar in the circumference of the moon; secondly, whether the reappearance of the sun is heralded by anything like a twilight on the moon's limb; thirdly, whether the corona disappears in separate parts; fourthly, whether beads or strings are seen; fifthly, whether the moon's circumference is visible beyond the sun's visible limb; sixthly, whether the brilliancy of the sun's limb is equal to or less than that of the portions of the disc immediately within it. The first appearance of white light should be noted by signal, as before.

26. It would now be interesting for the naked-eye observer to remark, if possible, whether the light of the sun appears to sweep over the country; whether there is any fluctuation of light on the ground, or on walls, &c.; and also whether dew or fog is formed.

27. Any observations for intensity, polarization, &c. which were omitted before the total obscuration, can now be made in a leisurely manner: and some measures of the interval between the cusps may be made with the sextant.

28. During the remainder of the eclipse there will be little of interest to be done, except to repeat the observations of radiation, and to make any observations applying to the meteorological state of the atmosphere. The instant of termination of the eclipse (a phænomenon which admits of accurate observation) should be noted. The actinometer-observations should be continued to a quarter of an hour after the last contact.

Appendix No. I.

The following suggestions, applying specially to the observation of the beads or strings sometimes seen, are principally extracted from the "Suggestions for the observation of the Annular Eclipse, Oct. 9, 1847," in the *Report of the Seventeenth Meeting of the British Association*, Transactions of the Sections, p. 16.

Whether the points of the cusps are rounded?

Whether in the neighbourhood of the cusp the limb either of the sun or moon appears distorted? Whether the beads appear steady or waving, disappearing and reappearing? Whether they present any peculiar changes when viewed through differently-

coloured glasses, the observer alternating the colours, which should be as dissimilar as possible, such as red and green?

Whether they are seen when the telescope is out of focus?

Whether they are seen when the eclipse is projected on a screen?

The drawing out of the beads into threads when very near junction; and whether they waver and change, and the number of them.

Whether before and after the formation of the threads the moon's dark disc is elongated towards the point of contact?

The beads are ascribed by some to lunar mountains. What mountains exist at that part of the limb?

The exact interval of time between the first formation of beads and the first complete contact, and that between the last complete contact and the last disappearance of beads (or other irregularities in or about the cusps), should be determined.

The remarkable fact of a recurrence of cusps, and the possible explanation of it, should be attentively considered.

In reference to the phænomena of the corona, and their possible explanation, the observer is referred to Professor Powell's papers in the *Memoirs of the Astronomical Society*, vol. xvi. p. 301, "On Luminous Rings round Shadows," and vol. xviii. p. 69, "On Irradiation."

Appendix No. II.

It is recommended to observers who may devote themselves especially to the phænomena of the rose-coloured prominences:—

1. Immediately before the total obscuration, to watch for the appearance of the prominences on all parts the sun's limb, but particularly at the part just about to be eclipsed by the moon's limb; and, the moment that the sun's bright edge is eclipsed, to watch in the direction of the moon's advance for any such prominence; to note mentally its form, and particularly the proportion of its height to its breadth at the base, which may be afterwards recorded in a sketch; and *to make quite sure* whether or not the moon gradually eclipses it.

2. In like manner, and with the same view, to direct the second scrutiny (immediately after the previous one) to the diametrically-opposite portion of the moon's limb, watching for the summits of any prominences, and whether they enlarge as the total eclipse proceeds.

3. In the third place, the observer having satisfied himself on the two previous points, will carefully examine the moon's limb all round, and may now record, on the previously prepared circular diagram, the *positions* of any such prominences round the moon's limb. Let this be done in the first instance without regard to their form or size, but only with regard to their distribution round

the circle; and let this be carefully verified once at least. Let him note whether any kind of arch of light connects two or more of the prominences.

4. Let the *dimensions* and *forms* of the prominences be studied. For the former purpose reference should be made to the two parallel threads in the eye-piece of the telescope. For the latter, observe—Whether the prominences have hard and permanent, or waving and ill-defined outlines. Whether they are invariably broadest at the base, and have on the whole a tapering shape. Whether they seem to stand erect, or whether any or all of them are aslant, like teeth on the edge of a circular saw. Whether any of them taper inwards next the dark limb of the moon: whether they appear isolated; and, if so, how the space between the red patch and the moon's limb is occupied. Whether the prominences vary in outline during the scrutiny. Whether any appear to grow up or to diminish; and, if so, whether such change is what the moon's motion would naturally account for.

5. Let the *illumination* of the prominences be studied. First, as to general colour; by inspecting them with the undefended eye, both with and without a telescope (without any dark glass). Next, as to distribution of colour, select a well-defined prominence and examine it all over *repeatedly* with a considerable magnifying power, and observe if it appears absolutely uniform in colour and brightness, or whether it shows any marks of structure or shadow or variation of tint. It seems very difficult to suggest any comparative experiment for recording the brightness of the illumination of the prominences.

6. As the total phase goes off, let the eye be fixed on one or more of the prominences, and see whether they instantly and totally vanish, or for how many seconds they can be kept in view.

It may be well to refer to M. Arago's narrative of what was seen in 1842 and on former occasions, in the *Annuaire du Bureau des Longitudes* for 1846, and to a paper by M. Faye in the *Comptes Rendus de l'Académie*, 1850, Nov. 4.

Appendix No. III.

Allusion having been made to instruments for determining the plane of polarization, it may be proper to give the following information:—

Nicol's prism is described in the *Edinburgh Philosophical Journal*, vol. xx. p. 83, and in the *Philosophical Magazine*, vol. iv. p. 289; and instruments on this construction are sold by Soleil in Paris and Watkins and Hill in London.

Savart's polariscope is described in Peclet's *Traité de Physique*, and is sold by the same artists.

The accompanying Map has been constructed principally from computations furnished to the Committee by Lieut. W. S. Stratford, R.N., Superintendent of the Nautical Almanac, verified in some parts by duplicate computations made under the direction of the Astronomer Royal.

The elements employed for computation of the geocentric places of the sun and moon are those of the Nautical Almanac. The sun's semidiameter, as given in the Nautical Almanac, is increased by $\frac{1}{1000}$ part, the moon's parallax by $\frac{1}{1200}$ part, and the moon's semidiameter by $\frac{1}{360}$ part, in conformity with the results of extensive investigations by the Astronomer Royal. It is to be remarked that the semidiameter thus found for the moon is that corresponding to an illuminated moon seen on a dark sky: if the apparent semidiameter when the dark moon is seen on the sun's bright disc be sensibly smaller, the breadth of the shadow and the duration of total darkness will be less than those given in the map.

The numbers in the 1st, 2nd, 3rd, 7th, and 8th columns are computed for the points opposite to them in the central line of shadow, but they will apply with sufficient accuracy for other neighbouring points within the shadow. The numbers in the 4th, 5th, and 6th columns are also computed for the points opposite to them in the central line of shadow; but they require large corrections to make them applicable to other points within the path of the shadow but not on its central line. These corrections are given by the numbers at the top and bottom of the map, corresponding to the various lines drawn longitudinally through the shadow's path. An example will best illustrate the mode of finding these corrections.

It is required to find the duration of total darkness and the angles from the upper point of the sun's disc for disappearance and reappearance, at Vladimir.

Opposite Vladimir, the duration of total darkness on the central line is 189^s. The longitudinal line passing through Vladimir, if traced to the bottom of the map, is found to correspond to the factor 0·7. Hence the duration of total darkness at Vladimir will be $189^s \times 0{\cdot}7 = 132^s$.

Opposite Vladimir, the angles from the sun's upper point at disappearance and reappearance are respectively 64° and 116°. The longitudinal line passing through Vladimir, if traced to the top of the map, is found to correspond to the correction 46° towards S. Hence the angles from the sun's upper point for disappearance and reappearance at Vladimir will be

$$64^\circ + 46^\circ = 110^\circ \text{ and } 116^\circ + 46^\circ = 162^\circ.$$

THE END.

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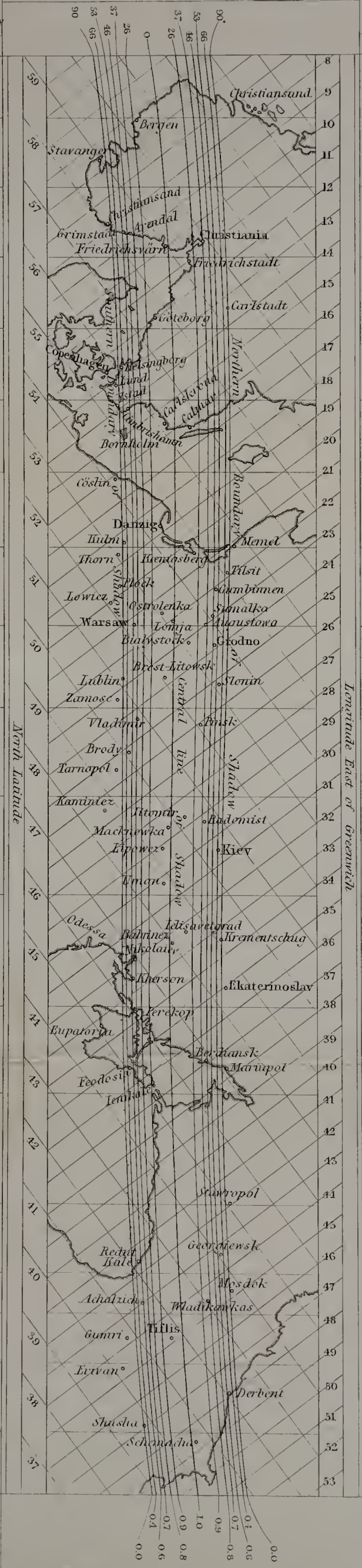
Total Eclipse of the Sun, 1851, July 28.

1	2	3	4
Local Time of beginning of Eclipse	Angle from Sun's upper point towards the West	Local Time of total obscuration of the Sun	Angle from Sun's upper point towards the East for disappearance on the central line of shadow
h m	°	h m	°
2 . 17	98	3 . 21	78
2 . 30	100	3 . 33	76
2 . 42	102	3 . 45	75
2 . 55	104	3 . 57	73
3 . 8	107	4 . 4	71
3 . 21	109	4 . 22	69
3 . 34	111	4 . 35	67
3 . 48	113	4 . 48	65
4 . 3	115	5 . 2	64
4 . 18	117	5 . 16	63
4 . 34	119	5 . 31	62
4 . 52	122	5 . 48	60
5 . 9	123	6 . 3	59
5 . 25	124	6 . 18	58
5 . 36	126	6 . 29	57
5 . 42	127	6 . 35	56
5 . 51	127	6 . 43	56
6 . 0	127	6 . 52	56
h m	°	h m	°
Local Time of beginning of Eclipse	Angle from Sun's upper point towards the West	Local Time of total obscuration of the Sun	Angle from Sun's upper point towards the East for disappearance on the central line of shadow

Correction to be applied to the Angles from Sun's upper point at disappearance and reappearance on the central line of shadow, to give the angles from Sun's upper point in other parts of the shadow.

Correction towards S. — Correction towards N.



Factor for multiplying the duration of darkness on the central line of shadow to give the duration of darkness in other parts of the shadow.

5	6	7	8
Duration of total Darkness on the central line of shadow	Angle from Sun's upper point towards the West for reappearance on the central line of shadow	Local Time of end of Eclipse	Angle from Sun's upper point towards the East
m s	°	h m	°
3 . 37	102	4 . 25	74
3 . 35	104	4 . 37	73
3 . 33	105	4 . 49	72
3 . 30	107	5 . 0	70
3 . 27	109	5 . 12	68
3 . 23	111	5 . 24	67
3 . 19	113	5 . 36	66
3 . 15	115	5 . 48	65
3 . 10	116	6 . 1	64
3 . 5	117	6 . 15	63
2 . 59	118	6 . 29	62
2 . 52	120	6 . 44	61
2 . 45	121	6 . 58	60
2 . 40	122	7 . 12	60
2 . 36	123		
2 . 34	124		
2 . 31	124		
2 . 26	124		
m s	°	h m	°
Duration of total Darkness on the central line of shadow	Angle from Sun's upper point towards the West for reappearance on the central line of shadow	Local Time of end of Eclipse	Angle from Sun's upper point towards the East

Sun sets before end of Eclipse

Sun sets before end of Eclipse

The times are in mean solar time of those points of the central line of shadow to which they are opposite. They correspond strictly to the phenomena seen at those points of the central line, and approximately to neighbouring points within the shadow.